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The goal of this project is to test the hypothesis that the expression of matrilysin in mammary epithelial cells plays a causal role in the progression and metastasis of mammary carcinomas using a transgenic mouse model system. We have successfully generated transgenic mice expressing the metalloproteinase matrilysin, under the control of the mammary specific MMTV promoter/enhancer. In this report we demonstrate that matrilysin accelerates the development of mammary tumors in the MMTV-*neu* transgenic animals. Current studies involve investigating the possibility that matrilysin is proteolytically processing members of the EGF/erbB signal transduction pathway, thereby constitutively activating this pathway and accelerating mammary tumor formation.

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## INTRODUCTION

Cell-matrix interactions are an important aspect to many biological processes. During processes such as mammary growth and neoplasia the extracellular matrix (ECM) is continuously degraded and remodeled. Proteins that degrade the extracellular matrix, such as matrix metalloproteinases (MMPs), clearly play a role in the interactions that occur within the extracellular environment. We have previously hypothesized that matrilysin, an epithelial specific MMP, is partly responsible for remodeling of the ECM during mammary development and tumorigenesis. To test our hypothesis, transgenic mice expressing matrilysin under the control of the mouse mammary tumor virus (MMTV) promoter/enhancer are being evaluated to investigate if overproduction of matrilysin alters mammary development and/or mammary tumorigenesis. In addition, we are also investigating the possibility of matrilysin altering growth factor and growth factor receptor interactions in mammary tumorigenesis by proteolytic processing.

Our previous annual report described the successfully generated transgenic animals that express native, active, and inactive human matrilysin in the mammary epithelium (*specific aim #1*). For review, three separate human matrilysin constructs have been used to develop three different transgenic lines: 1) a native, or wild-type transgene, 2) a constitutively activated transgene, and 3) an inactive matrilysin transgene. The constitutively active construct contains a mutation that results in spontaneous activation of the enzyme, therefore circumventing any dependence on activation by exogenous factors. A comparison of the results from the native and active matrilysin constructs will give an indication of the availability of activators of matrilysin in the mammary environment. The third construct encodes a matrilysin protein that lacks proteolytic activity due to the presence of an inactivating mutation. The use of this mutant will determine if any observed effect of matrilysin in this model is due to its proteolytic activity.

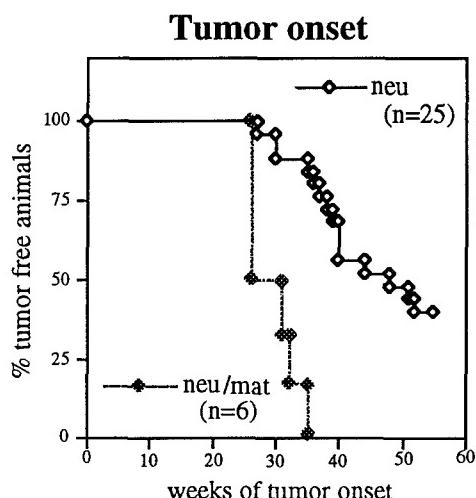
In this report we focus on the studies to address whether mammary tumorigenesis can be modified by overexpression of native matrilysin (*specific aim #2*). To address this question, we have mated mice expressing the wild-type matrilysin protein with those expressing the oncogene *neu* under the control of the MMTV promoter (1). Mice expressing the active and inactive matrilysin are currently being mated to the MMTV-*neu* animals. *neu/c-erbB2* has been observed to be amplified and overexpressed in a significant number of human breast cancers (2). Several studies have shown that the degree of amplification is inversely correlated to a poor clinical outcome (2,3). Overexpression of the *neu* product in the murine mammary epithelium results in the appearance of focal mammary tumors in multiparous females by approximately 205 days that metastasized to the lungs in 70% of tumor bearing animals (1).

## PROGRESS

*Examining the effects of matrilysin overexpression on mammary tumor formation, growth, and progression (specific aim #2).*

Transgenic mice expressing the wild-type matrilysin protein under the control of the MMTV promoter have been mated to the MMTV-*neu* transgenic animals. The resulting mammary tumors have been analyzed for the time and frequency of onset, growth rate, and presence of metastasis. As indicated in Figure 1, the matrilysin/*neu* females (closed diamonds) develop mammary tumors at an accelerated rate and higher frequency than the *neu* control females (open diamonds). However, we have observed no obvious difference in the growth rate or the development of metastasis in the matrilysin/*neu* mice when compared to the *neu* controls (Table I).

These results are remarkably similar to results recently obtained by Drs. R.J. Coffey, Jr., Vanderbilt University, and W. Muller, McMaster University, in which they crossed the MMTV-TGF $\alpha$  (4) transgenics with the MMTV-*neu* mice (1) and also observed significant acceleration in the onset of tumor development (personal communication). These results have led us to the possibility that there is a connection between matrilysin and the EGF/erbB receptor signal transduction pathways that may be related to accelerated mammary tumor growth. One potential mechanism to explain the similarities in the accelerated response of MMTV-*neu* tumors to both TGF $\alpha$  and matrilysin may be that matrilysin is responsible for the proteolytic processing of the EGF/erbB tyrosine kinase receptor family and/or their growth factor ligands.



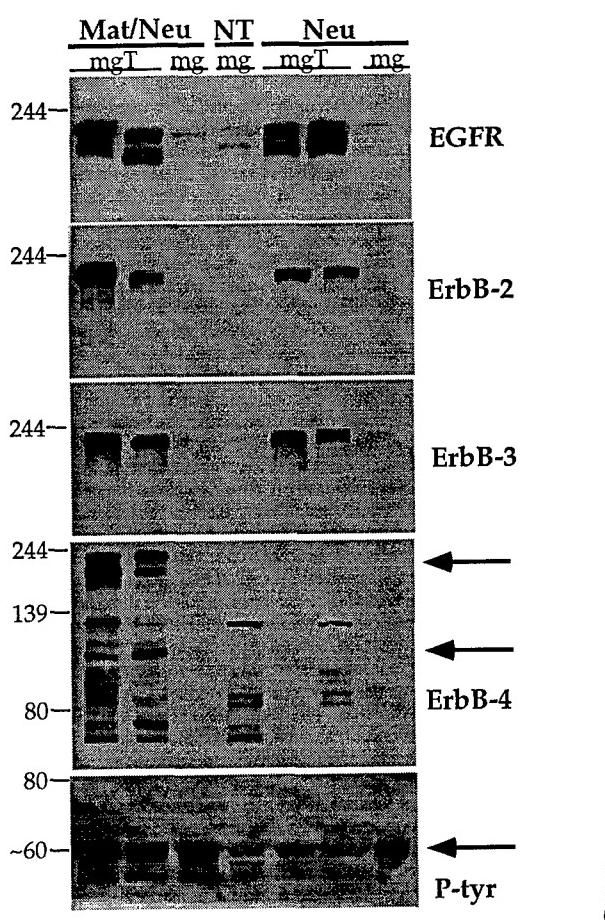
**Figure 1: Mammary tumor onset curve.**  
MAT/neu transgenics develop mammary tumors with an increased frequency and shorter latency period when compared to the *neu* animals. At 35 weeks of age, 100% of the MAT/neu females have developed mammary tumors, while only 17% of the *neu* females had tumors. Even at 50 weeks of age, only 54% of the *neu* females had developed mammary tumors.

	Mat/Neu	Neu
Tumor Growth Rate	$14.0 \pm 6.5$ days (n = 12 tumors)	$15.5 \pm 6.7$ days (n = 11 tumors)
Lung Metastasis	80% (4/5)	73% (8/11)
Ave. # Tumors per mouse	$2.8 \pm 1.7$ tumors (n = 6 animals)	$1.5 \pm 0.5$ tumors (n = 11 animals)
Ave. # of pregnancies	$0.7 \pm 0.8$ preg. (n = 6 animals)	$0.7 \pm 0.7$ preg. (n = 11 animals)

**Table I: Comparison of MAT/neu and *neu* transgenic animals.** The *tumor growth rate* was determined by physically measuring the tumors on a weekly basis. Tumor volume was then calculated and graphed against days of tumor growth. Using a log scale, the total number of days for the tumor to double in size was calculated. The percent *metastasis* was determined by both macro and microscopic analysis.

\*\*Note: This page contains confidential unpublished results.

Current studies involve the examination of members of the EGF/erbB signalling pathway as potential substrates for matrilysin's catalytic activity. Immunoprecipitations and Western blot analysis have been used to determine the levels, processed and phosphorylation state of erbB-1 (EGF receptor), erbB-2 (*neu*), erbB-3 and erbB-4 in extracts from mammary glands and mammary gland tumors from the matrilysin/*neu* and *neu* control animals (Figure 2). As shown in figure 2, there seems to be an increase in erbB-4 protein, and the presence of smaller, potentially proteolytically processed forms of the receptor in the matrilysin/*neu* glands. Additionally, there is an increase in tyrosine phosphorylated proteins when compared to the *neu* control glands.



**Figure 2: Analysis of erbB receptor expression in transgenic tumors.**

Mammary glands (mg) or mammary gland tumors (mgT) were removed from nontransgenic control (NT), MMTV-*neu* (*Neu*) or MMTV-matrilysin/*neu* (Mat/*Neu*) females. 100 $\mu$ g of protein was separated on an 8% acrylamide gel, transferred to nitrocellulose, and probed using antibodies specific for each erbB family member (Santa Cruz) or for mouse phosphotyrosine (Upstate Biotechnology).

**\*\*Note: This page contains confidential unpublished results.**

To support our preliminary findings, recent reports have demonstrated that metalloproteinase activity is involved in the processing of tumor necrosis factor- $\alpha$  (5), and heparin binding-epidermal growth factor (HB-EGF) (6), releasing this growth factor to become a soluble, paracrine factor (7). Most recently, processing of the erbB-4 receptor as a result of protein kinase C activation has been reported (8), which further supports the possibility that matrilysin may be involved in this proteolytic event.

We plan to pursue our findings by using a cell culture system derived from the matrilysin/*neu* and the *neu* mammary tumors. In addition, we will continue our experiments using mammary tumor extracts on the EGF/erbB receptors and also expand our efforts to the growth factor receptor ligands, namely EGF, TGF $\alpha$ , and heregulin to determine if their expression or processing is altered by overexpression of matrilysin.

## FUTURE STUDIES

*Determining if matrilysin expression contributes to mammary tumor formation or progression (specific aim #3).*

Initially we had intended to determine if metalloproteinase expression in general contributes to mammary tumor formation or progression by generating transgenic mice overexpressing the inhibitor of metalloproteinases, TIMP, and then testing the effect of TIMP expression on the progression of chemically-induced mammary tumors. Since that time, our laboratory has generated matrilysin null animals. Using this model system we can specifically test whether matrilysin contributes to mammary tumor formation or progression. We have begun mating the matrilysin null animals with MMTV-polyomavirus middle T oncogene (MT) transgenic animals that develop multiple mammary tumors by approximately 80 days (9). We have previously determined that the mammary tumors that develop in the MMTV-MT mice do express endogenous matrilysin, so these experiments were designed to address if tumor growth, and/or metastasis is decreased by the absence of matrilysin.

## CONCLUSIONS

The initial results obtained from the matrilysin/*neu* transgenic animals demonstrate that matrilysin, like TGF $\alpha$ , accelerated the formation of mammary tumors. We are currently investigating the possibility that matrilysin may be responsible for the proteolytic processing of the EGF/erbB tyrosine kinase receptor family and/or their growth factor ligands, thereby accelerating mammary tumor formation. Future studies using matrilysin null animals will determine if matrilysin specifically contributes to the formation and progression of mammary tumorigenesis.

## ABSTRACTS

Rudolph, L.A. and Matrisian, L.M. Overexpression of human matrilysin induces ErbB-4 expression and processing and results in a shorter latency period of mammary tumors in transgenic animals. *Clinical and Experimental Metastasis*, 14 (Supp. 1):64, 1996. Presented at the Sixth International Congress of the Metastasis Research Society, Aula of the University of Gent, Gent, Belgium. Sept., 1996.

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Rudolph, L.A. and Matrisian, L.M. Alterations resulting from the overexpression of the matrix metalloproteinase matrilysin in the murine mammary gland. Presented at the Mammary Gland Biology Gordon Conference, New London, NH, June 1995.

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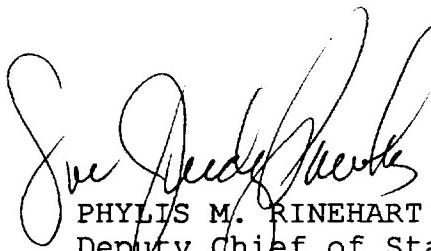
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